Nitrogen, Aldicarb, and Cover Crop Effects on Cotton Yield and Fiber Properties

Philip J. Bauer* and Mitchell E. Roof

ABSTRACT

Thrips, primarily *Frankliniella* spp., can damage cotton (*Gossypium hirsutum* L.) seedlings. The objectives of this study were to determine the effect of winter cover crops on thrips populations in cotton and to assess the yield and fiber quality response to cover crops and N fertilizer rate with and without thrips protection. A field experiment was conducted on a Bonneau loamy sand soil (loamy, siliceous, thermic, Arenic Paleudult) from 1996 through 1998. Treatments were cover crops, N fertilizer rate, and aldicarb rate. Cover crops were rye (*Secale cereale* L.), crimson clover (*Trifolium incarnatum* L.), a clover + rye mixture, and winter fallow. Nitrogen levels were 0, 78, and 112 kg N ha^{-1}. Aldicarb levels were 0 and 1.18 kg a.i. ha^{-1}. Aldicarb reduced thrips populations. For plots without aldicarb, differences among winter covers occurred at one sampling time in 1998 when fallow had more thrips than the other three winter covers. Aldicarb increased yield by 9% in 1996, 48% in 1997, and 35% in 1998. In 1997 and 1998, yield increases with aldicarb were greater in the winter cover and N treatment combinations that provided higher total N to the crop. The 0 kg N ha^{-1} rate tended to have lower yield, fiber length, length uniformity, fiber strength, micronaire, and Hunter's +b than the other two N rates. Aldicarb generally increased the value of these fiber properties each year. Including agronomic practices in assessing control measures may improve integrated pest management strategies for thrips in conservation tillage systems.

Conservation tillage systems are being widely used by growers for cotton production throughout the southeastern USA. According to the 2002 National Crop Residue Management Survey, acres of cotton grown with no-tillage in this region have increased by 750% over the last 10 yr, and the southeast region has 85% of the cotton grown without tillage in the USA (http://www.ctic.purdue.edu/Core4/CT/ctsurvey/2002/RegionalSynopses.html; verified 17 Nov. 2003). Conservation tillage systems provide a more diverse habitat for insects than conventional tillage production systems. All et al. (1992) found fewer tobacco thrips (*Frankliniella fusca* Hinds) in no-tillage than in a conventional system with surface tillage and concluded that use of no-tillage may enhance integrated pest management (IPM) control of that pest.

Cover crops can improve yield in conservation tillage cropping systems for cotton (Bauer and Busscher, 1996; Raper et al., 2000). Both legume and nonlegume cover crops affect N fertilizer management. The value of legumes as a source of N for subsequent crops has been well documented (Hoyt and Hargrove, 1986; Reeves, 1994), and substantial work in this area has been conducted with modern cotton cultivars (Touchton et al., 1984; Bauer et al., 1993; Daniel et al., 1999; Larson et al., 2001). Grass cover crop residues generally have a high C/N ratio, which causes N immobilization and the need for higher N fertilizer rates than when no cover crop is used (Reeves, 1994).

The economic damage caused by thrips to cotton is substantial. Hardee and Burris (2002) reported that early-season thrips were the third most serious arthropod pest of the U.S. cotton crop in 2001, reducing the yield of the U.S. crop by 0.795%. Thrips are phytophagous insects with piercing mouthparts. The damage they cause is especially severe on seedling cotton. Depending on the growing season and the degree of damage, cotton plants can often overcome this early-season stress. In areas with long growing seasons, damage does not always reduce yield (Sadras and Wilson, 1998; Terry, 1992). In areas with relatively short growing seasons, where stand and yield losses can be substantial, preventative in-furrow applications of aldicarb {2-methyl-2-(methylthio)propanal *O*-[(methylamino)carbonyl]oxime} are commonly used to control thrips (All et al., 1995). Also, Terry (1992) found that fiber quality, a substantial component of the economic returns to growers, was not greatly affected by thrips damage. Additional information on cropping system combinations that affect thrips populations may help improve IPM measures for this pest.

Our hypothesis was that the attractiveness of cotton seedlings to thrips would be influenced by winter cover treatment, and this would influence the yield and quality response of cotton to aldicarb application. The objectives of this study were to determine the effect of winter cover crops on thrips populations in cotton seedlings and to assess how thrips protection influenced the yield and fiber quality response of cotton to cover crops and N fertilizer rate.

MATERIALS AND METHODS

This 3-yr study was conducted at Clemson University's Pee Dee Research and Education Center near Florence, SC, in a field with a soil type consisting primarily of Bonneau loamy sand. The same plots were used each year, and there was no re-randomization of treatments between years. Treatments consisted of winter cover (rye, crimson clover, clover + rye mixture, and fallow), N rate (0, 78, and 112 kg N ha^{-1}), and aldicarb (0 and 1.18 kg a.i. ha^{-1}). Experimental design was split-split plot with winter cover as main plots, N rates as subplots, and aldicarb rates as sub-subplots. Sub-subplot size was four cotton rows that were 1-m wide and 15.2 m long. The experiment had four replicates each year.

Before beginning the experiment in 1995, all plots were chisel-plowed and disked on 3 Oct. 1995. Thereafter, the only tillage in the experiment was the use of in-row subsoiling

P.J. Bauer, USDA-ARS, Coastal Plains Soil, Water, and Plant Res. Cent., 2611 W. Lucas St., Florence, SC 29501-1242; and M.E. Roof, Clemson Univ., Pee Dee Res. and Educ. Cent., Florence, SC 29506-9706. Received 23 Sept. 2002. *Corresponding author (bauer@florence.ars.usda.gov).

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677 S. Segoe Rd., Madison, WI 53711 USA

Abbreviations: IPM, integrated pest management.

before planting cotton each year. Cover crops were planted on 19 Oct. 1995, 18 Oct. 1996, and 4 Nov. 1997 with a John Deere model 750[1] grain drill that had rows spaced 19.1 cm apart. Rye was seeded at a depth of 3.2 cm, and clover was planted 1.9 cm deep. Seeding rates were 134 kg ha^{-1} for rye and 22 kg ha^{-1} for crimson clover. For the rye + clover mixture, we planted rye where the cotton rows were to be and clover between the cotton rows. To accomplish this, plots were planted twice. Rye, which was planted deeper, was planted first. In the first pass, the seed openers where the clover was to be planted were blocked, and rye was planted with the same depth and seeding rate settings as was used for the rye winter cover treatment level. After the rye was planted in the clover + rye mix plots, those seed openers were blocked, and clover was planted into the cotton midrow areas using seeding rate and depth settings that were used for the clover treatment level.

Biomass of the cover crops and the winter weeds was determined by collecting samples [0.57 m^2 for rye and clover (three 1-m-long sections of row), 1.0 m^2 for winter weeds, and 0.38 m^2 (two 1-m-long sections of row) of the rye and 0.57 m^2 of the clover in the clover + rye mixture] on 22 Apr. 1996, 17 Apr. 1997, and 24 Apr. 1998. A larger sampling area was collected from the fallow plots because weed growth was more variable than the growth of the cover crops and to greater ensure a representative biomass sample for N analysis. Samples were dried at 60°C for 3d days, weighed, and ground for N analysis. Glyphosate [*N*-(phosphonomethyl)glycine] (1.12 kg a.i. ha^{-1}) was applied on 24 Apr. 1996, 30 Apr. 1997, and 24 Apr. 1998 to the entire experimental area to kill existing vegetation.

All plots were in-row subsoiled to a depth of 30 cm just before planting cotton. Cotton (cultivar Deltapine Acala 90) was seeded on 9 May 1996, 7 May 1997, and 5 May 1998 with a Case-IH 900 series planter. Insecticide application attachments on the planter were engaged for plots receiving aldicarb and disengaged for plots where aldicarb was not to be applied. Weeds were controlled by applying recommended pre- and postemergence herbicides and by hand weeding. Before planting the cover crops in the fall of 1995, a fertilizer application containing 28 kg N ha^{-1}, 56 kg P_2O_5 ha^{-1}, and 56 kg K_2O ha^{-1} was made on 12 Oct. 1995. After that, applications of lime, P, K, and Mn were made in April before planting cotton based on soil test results and Clemson University Extension recommendations for nonirrigated cotton. Annual applications of S (22.4 kg ha^{-1}) and B (0.6 kg ha^{-1}) were included with the preplant fertilizer.

For the N treatment levels, ammonium nitrate was applied in a split application to the plots receiving 78 and 112 kg N ha^{-1}. About 1 wk before planting cotton, 34 kg N ha^{-1} was applied to the plots assigned the 78 kg N ha^{-1} treatment level, and 68 kg N ha^{-1} was broadcast-applied to the plots assigned 112 kg N ha^{-1}. The remainder of the N (44 kg ha^{-1}) was applied in a band application when the first flower buds on the plants were visible (about 1 mo after planting).

Thrips densities were measured on the seedling plants twice each year (22 and 30 May in 1996, 19 and 26 May in 1997, and 18 and 26 May in 1998). At both dates, adult and immature thrips were determined by placing a white plastic bowl underneath five randomly selected plants. The plants were shaken vigorously, and the number of each type of thrips in the bowl was recorded. Damage ratings due to thrips were made on 10 cotton plants from each plot on 31 May 1996, 5 June 1997, and 7 June 1998. The scale used for damage ratings was as follows: 1 = no damage; 2 = slight crinkling of one or more true leaves, no apparent damage to terminal; 3 = moderate crinkling of one or more true leaves, some terminal damage may be present; 4 = true leaves both crinkled and stunted, terminal damaged and stunted; 5 = true leaves severely crinkled and stunted, terminal severely damaged; and 6 = dead plant. The average rating of the 10 plants is reported.

In-season N status of the crop was determined by measuring the N concentration of the uppermost fully expanded leaf of cotton plants on 10 July 1996 and by measuring the petiole NO_3–N concentration of leaves in the same position on 29 July 1997 and 9 July 1998. In 1997 and 1998, we measured petiole NO_3–N of uppermost fully expanded leaves instead of leaf N because leaf N is a measure of the accumulation of N at the top of the plants while petiole NO_3–N is an indication of the flux of N to the top of the plants at the time of sampling. On each date, 25 leaf blades or petioles were collected, dried for 3 d at 65°C, and then ground.

Winter cereal plant tissue and cotton leaf blade N analysis was conducted by the Clemson University Extension Agriculture Service Laboratory. Nitrogen concentration of the tissues was determined with a Kjeltec System 2300 Distilling Unit[1] (Tecator Co., Hoganas, Sweden) after block digestion. Petiole NO_3–N was determined with an ion-specific electrode after extraction with $Al_2(SO_4)$ solution (Baker and Thompson, 1992).

Cotton was chemically defoliated on 9 Sept. 1996, 2 Oct. 1997, and 9 Sept. 1998. Defoliation chemicals and rates used in 1996 and 1997 were thidiazuron (*N*-phenyl-*N*′-1,2,3-thiadazol-5-ylurea) at 0.06 kg a.i. ha^{-1}; *S,S,S*-tributyl phosphorotithioate at 0.84 kg a.i. ha^{-1}; and ethephon [(2-chloroethyl) phosphonic acid] at 1.12 kg a.i. ha^{-1}. In 1998, only thidiazuron was applied. The two center rows of each plot were harvested with a spindle picker on 11 Oct. 1996, 21 Oct. 1997, and 29 Sept. 1998. Plot weights were determined, and seed cotton samples were ginned for determination of lint percentage and fiber properties. Fiber samples were subjected to high-volume instrumentation analysis for fiber length, length uniformity, bundle strength, elongation, micronaire, and color. After cotton harvest, final plant populations were determined by counting all plants in the center two rows of each plot. Plant height was then measured on five plants in each plot.

All data were subjected to analysis of variance, and sources of variation were considered significant if the probability of

[1] Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the USDA and does not imply approval of a product to the exclusion of others that may be suitable.

Table 1. Biomass and N content of winter cover crops in April of 1996, 1997, and 1998 at Florence, SC.

	1996		1997		1998	
Cover	**Biomass**	**N content**	**Biomass**	**N content**	**Biomass**	**N content**
	kg ha^{-1}	kg N ha^{-1}	kg ha^{-1}	kg N ha^{-1}	kg ha^{-1}	kg N ha^{-1}
Fallow	497	5	687	9	515	6
Rye	2509	17	896	8	686	5
Clover	1374	32	2231	43	1764	36
Rye + clover	3075	38	1637	25	2172	37
LSD (0.05)	1177	14	451	6	313	6

Table 2. Effect of winter cover and aldicarb on early-season adult thrips numbers at 2 and 3 wk after planting and on thrips damage to the cotton plants. Damage ratings were made on 31 May 1996, 5 June 1997, and 7 June 1998.

		Adult thrips (no. per five plants)					
		2 wk after planting		3 wk after planting		Thrips damage (0–5 rating)	
Year	Cover	Control	Aldicarb	Control	Aldicarb	Control	Aldicarb
1996	Fallow	15.9	4.4	1.6	0.9	2.8†	1.2
	Rye	11.7	2.1	1.7	0.3	2.2	1.1
	Clover	9.2	3.8	1.9	0.3	2.5	1.2
	Rye + clover	14.8	3.1	1.0	0.2	1.9	1.1
	Mean	12.9**	3.3	1.5**	0.4	2.3**	1.1
1997	Fallow	9.8	2.3	5.4	0.8	3.5	1.9
	Rye	17.0	3.2	6.7	1.8	4.3	1.0
	Clover	10.9	1.2	3.4	0.6	3.8	1.0
	Rye + clover	13.1	2.8	5.0	1.2	3.5	1.3
	Mean	12.7**	2.4	5.1**	1.1	3.8**	1.3
1998	Fallow	8.8	0.1	22.8‡	0.5	2.1	1.0
	Rye	8.5	1.0	9.3	0.3	2.0	1.0
	Clover	6.8	0.6	6.3	0.8	2.1	1.0
	Rye + clover	6.7	0.4	8.8	0.3	2.0	1.0
	Mean	7.7**	0.5	11.8**	0.5	2.0**	1.0

** Indicates differences between means for levels of aldicarb were significant ($P \leq 0.01$).
† The winter cover × aldicarb interaction was significant in 1996; $LSD_{(0.05)} = 0.22$.
‡ The winter cover × aldicarb interaction was significant at 3 wk after planting in 1998; $LSD_{(0.05)} = 6.4$.

a greater F value was ≤0.05. Treatment means for thrips populations, plant damage by thrips, plant stands, lint yield, and fiber properties were separated with an LSD when F values from analysis of variance were significant. For plant N and plant height, treatment means were used in quadratic regression equations in relating these independent variables to the sum of the N fertilizer applied and the N in the winter cover crop. When the aldicarb main effect and/or interactions with aldicarb were significant, separate equations were calculated for the two levels of insecticide application. Because the cover crop × N rate interaction was significant for yield, fiber strength, and micronaire in 1998, regression equations were also computed relating these variables to the sum of N in the fertilizer and in the winter cover.

RESULTS AND DISCUSSION

Cover Crop Production

The winter weeds (fallow treatment) were low in biomass and N accumulation in all 3 yr of the study (Table 1). The relatively high biomass for the rye in 1996 (compared with 1997 and 1998) is at least partially due to the 28 kg N ha^{-1} application made just before planting the cover crops in 1995. No fertilizer applications were made before planting the cover crops in the fall of 1996 and 1997, and rye biomass and N did not differ from the winter weeds in the fallow winter cover in either of those 2 yr. The biomass production of the rye was lower than that of the clover and the clover + rye in 1997 and 1998. The clover and the clover + rye winter covers had higher N accumulation than either of the nonlegume cover crops in all 3 yr of the study. In 2 of the 3 yr (1996 and 1998), the clover + rye winter cover had higher biomass than the clover alone, but these two winter cover treatments did not differ for N accumulation in those 2 yr. Clover had higher biomass and N accumulation than the clover + rye cover in 1997.

Thrips Numbers and Damage

Adult thrips were present in at least some of the treatment combinations at all sampling dates in each year. Immature thrips were only present at the second sampling dates in 1997 and 1998, and then only in plots not receiving aldicarb. Number of immature thrips did not correlate with seedling damage or any other variable measured in those 2 yr, so only adult thrips data are presented.

Aldicarb treatment reduced the number of thrips on the cotton plants compared with cotton that was grown without aldicarb each year (Table 2). For cotton treated with aldicarb, thrips numbers were not affected by winter cover treatment at either sampling date in any year, and N fertilization was not a factor in thrips numbers (data not shown).

Although the sampling times were not statistically compared, differences in thrips numbers between the second and third week after planting differed considerably among years for cotton grown without aldicarb. Between these two sampling times, thrips numbers de-

Table 3. Effect of winter cover and aldicarb on cotton plant populations.

		Cotton plant population		
Year	Cover	Control	Aldicarb	Mean
		plants m^{-2}		
1996	Fallow	10.1	7.9	9.0†
	Rye	8.5	6.7	7.6
	Clover	8.5	6.6	7.5
	Rye + clover	8.8	6.9	7.9
	Mean	8.9**	7.0	
1997	Fallow	7.1	8.2	7.6
	Rye	6.9	8.9	7.9
	Clover	3.8	7.0	5.4
	Rye + clover	5.7	8.3	7.0
	Mean	5.9**	8.1	
1998	Fallow	11.8‡	13.4	12.6†
	Rye	11.8	12.8	12.3
	Clover	6.3	10.2	8.3
	Rye + clover	5.7	11.4	8.6
	Mean	8.9**	12.0	

** Indicates differences between means for aldicarb were significant ($P \leq 0.01$).
† The cover crop main effect was significant in 1996 [$LSD_{(0.05)} = 1.0$] and in 1998 [$LSD_{(0.05)} = 1.3$].
‡ The winter cover × aldicarb interaction was significant at 3 wk after planting in 1998; $LSD_{(0.05)} = 1.6$.

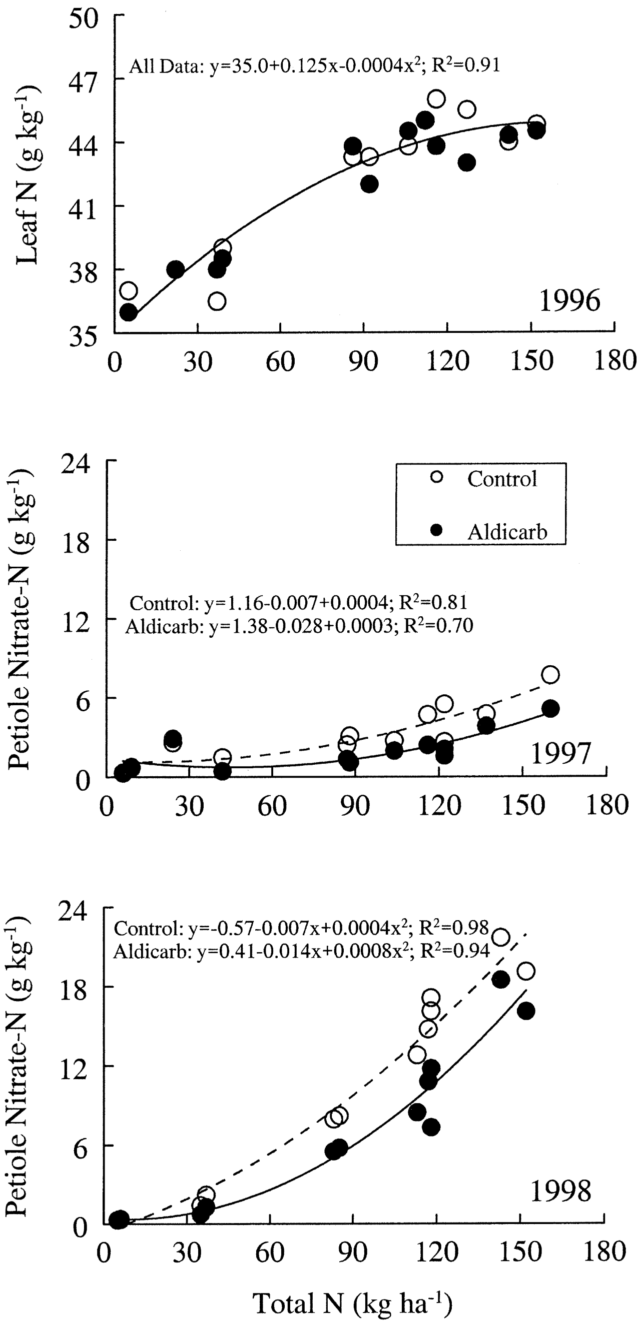

Fig. 1. Effect of total N in the cover crop plus fertilizer N to midseason leaf N concentration (1996) or petiole nitrate N concentration (1997 and 1998) with and without aldicarb. Aldicarb did not have an effect on leaf N in 1996, so the regression equation is for all data points.

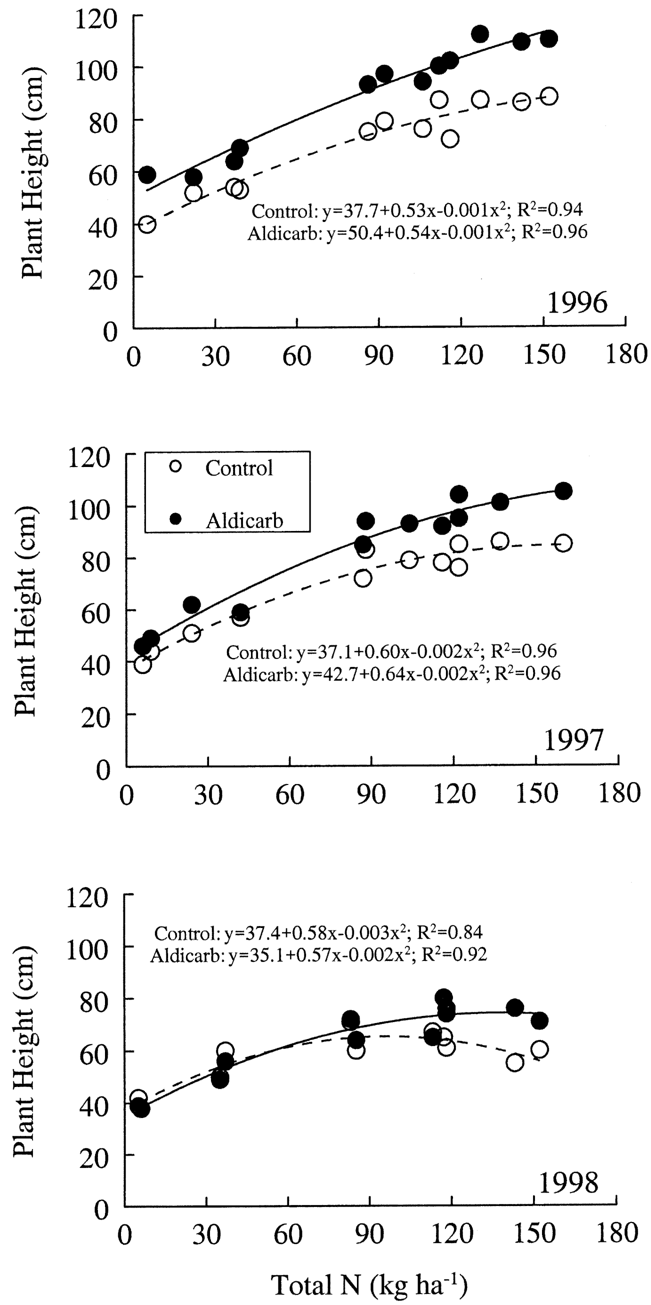

Fig. 2. Effect of total N in the cover crop plus fertilizer N on plant height at the end of each season with and without aldicarb.

clined 88% in 1996 and 60% in 1997 (Table 2). In 1998, there was a substantial increase in adult thrips numbers in the fallow treatment between 2 and 3 wk after planting, but no substantial difference in thrips numbers were observed between sampling times for the rye, clover, and rye + clover mixture. The large increase in thrips numbers in the fallow treatment in 1998 caused a winter cover × aldicarb interaction at the 3-wk-after-planting sampling date (Table 2). At that sampling time in that year, thrips numbers were higher for the winter fallow treatment than for the other three winter covers for cotton not treated with aldicarb.

Aldicarb reduced thrips damage to the cotton seedlings, and years were similar in average damage to the cotton seedlings when aldicarb was applied (Table 2). For cotton not protected with aldicarb, plant damage was higher in 1997 than in 1996 and 1998. In 1996, a significant winter cover × aldicarb interaction occurred for plant damage caused by thrips as differences among winter cover treatments occurred only when aldicarb was not applied. The ranking of winter covers for damage to cotton seedlings when aldicarb was not applied in that year was fallow > clover > rye > clover + rye (Table 2). In 1997, variability for plant damage was quite large in the experiment [coefficient of variation (CV) = 47%] compared with 1996 (CV = 15%), and this large

Table 4. Effect of winter cover, N rate, and aldicarb on cotton lint yield in 1996, 1997, and 1998.

		N fertilizer rate (kg ha^{-1})					
		0		78		112	
Year	Cover	Control	Aldicarb	Control	Aldicarb	Control	Aldicarb
		lint yield, kg ha^{-1}					
1996	Fallow	334	443	842	997	887	1005
	Rye	438	425	816	1004	929	1066
	Clover	516	511	892	1009	1014	1058
	Rye + clover	421	445	908	1094	1106	988
	Mean	427†	456	864	1026	983	1029
	N rate mean	442‡		945		1007	
1997	Fallow	113	247	411	708	621	883
	Rye	113	228	400	813	497	1022
	Clover	117	310	276	767	259	713
	Rye + clover	169	363	568	897	516	892
	Mean	133	287	413	796	473	878
	N rate mean	210		605		676	
1998	Fallow	204	314	427	603	322	601
	Rye	284	353	521	657	389	639
	Clover	463	521	311	532	174	415
	Rye + clover	379	520	292	543	288	489
	Mean	332	427	388	584	291	535
	N rate mean	380		486		414	

† The N rate × aldicarb interaction was significant ($P \leq 0.05$) only in 1997 and 1998. $LSD_{(0.05)}$ values are 111 kg ha^{-1} in 1997 and 64 kg ha^{-1} in 1998.
‡ The $LSD_{(0.05)}$ values for comparing N rate means are 71 kg ha^{-1} in 1996, 89 kg ha^{-1} in 1997, and 48 kg ha^{-1} in 1998.

amount of variation resulted in no significant differences occurring among winter cover treatments even though the range in mean damage was about the same as the range in 1996. All winter cover treatments not treated with aldicarb had similar plant damage due to thrips in 1998 (Table 2) even though the only significant differences among winter cover treatments for thrips numbers occurred at 3 wk after planting in that year (Table 2).

Cotton Production

Aldicarb-treated plots had lower plant stands (compared with the control) in 1996 but higher plant stands in 1997 and 1998 (Table 3). We do not know why results from 1996 differed from the other 2 yr. In 1998, a significant winter cover × aldicarb interaction occurred where differences between the nonlegume winter cover treatments and the clover and rye + clover winter covers were much greater without aldicarb than with aldicarb (Table 3). Although not significant, a similar trend for plant stand occurred among winter cover treatments in 1997. Rothrock and Hargrove (1987) sampled soil from plots after several consecutive years of growing cover crops and found soil *Pythium* sp. populations increased in a subsequent grain crop following crimson clover compared with no cover crop or rye. The lower stands following the clover and the clover + rye winter covers compared with fallow and rye may have been a result of increased plant stress of both disease and thrips damage. When significant, differences for the legume treatments when aldicarb was applied were much less than for the control. Further research into mechanisms that affect survival of seedlings with thrips damage in the presence of legume cover crops appears warranted.

The N status of uppermost fully expanded leaves during the season (leaf N in 1996 and petiole NO_3–N in the other 2 yr) and plant height at the end of the season were closely related to the amount of N in the cover crop plus fertilizer N (Fig. 1 and 2). Leaf N contents of uppermost fully expanded leaves increased as total N increased up to approximately 90 kg ha^{-1} in 1996 (Fig. 1). Beyond 90 kg ha^{-1}, there was little difference between N amounts for leaf N. In both 1997 and 1998, petiole NO_3–N increased as total N increased. Petiole NO_3–N concentrations were lower in 1997 than in 1998 probably because the time of sampling was 12 wk after planting in 1997 but only 9 wk after planting in 1998. Previously, petiole NO_3–N concentrations of cotton with adequate N nutrition declined from approximately 15 g kg^{-1} at 9 wk after planting to approximately 5 g kg^{-1} at 12 wk after planting on a similar soil type (Bauer et al., 1993).

Aldicarb did not affect leaf N in 1996. Average petiole NO_3–N concentrations in 1997 and 1998 were greater for the cotton that did not receive aldicarb at planting than for cotton that did ($P \leq 0.01$ both years), and as total N levels increased, the difference between aldicarb-treated and untreated cotton became greater (Fig. 1). Higher petiole NO_3–N for the cotton that did not receive aldicarb is likely due to a delay in growth of the crop due to the thrips damage (Table 2), with fewer bolls on the plants at the time of sampling.

Cotton plant height increased as total N increased in 1996 and 1997 (Fig. 2). Although plants receiving aldicarb were taller at all N levels, the difference between aldicarb-treated and untreated cotton increased as total N increased. Cotton plant growth was reduced in 1998 because of low rainfall during the growing season, and differences between the aldicarb treatments for plant height occurred only at the high total N levels. Shorter plants at the high N levels for the cotton not receiving aldicarb in all years may have been due to the delayed growth caused by the thrips damage. Delays in growth would have less effect on plant height where N was limiting (all years where total N was low) or where water was limiting (1998) because these environmental factors would limit growth rather than season length.

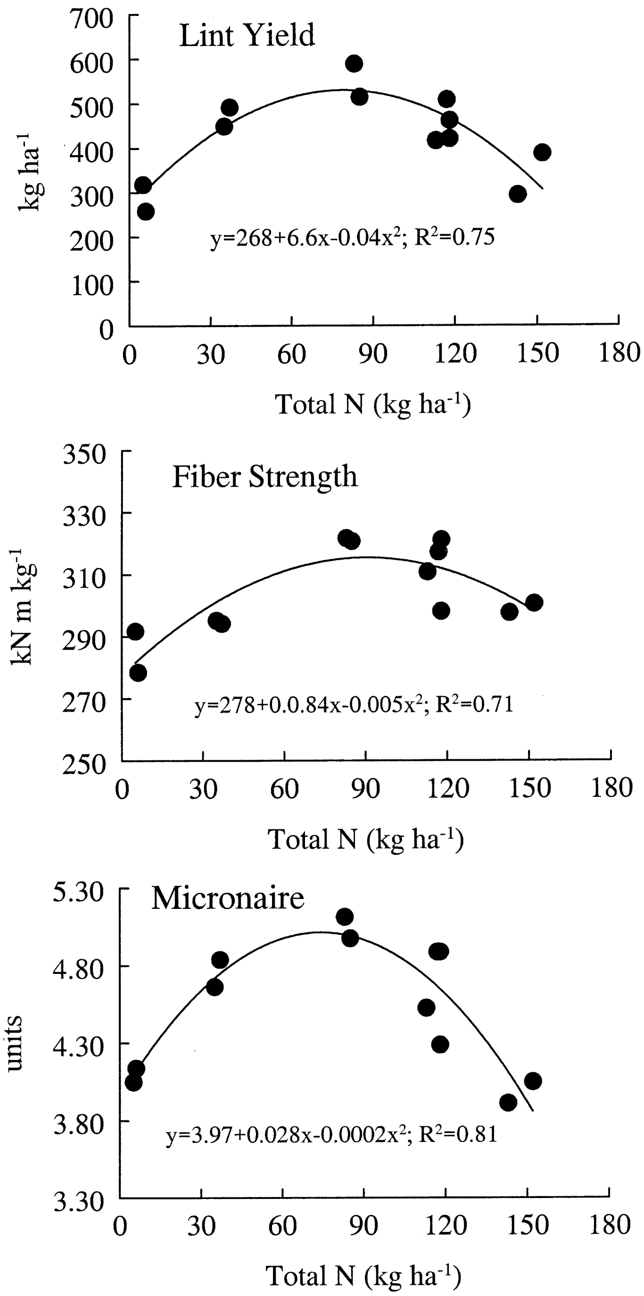

Fig. 3. Effect of total N in the cover crop plus fertilizer N on lint yield, fiber strength, and fiber micronaire in 1998. Means are averaged over both aldicarb levels.

Among years, the crop was tallest (Fig. 2) and had highest average yield (Table 4) in 1996. The crop was shortest and had lowest yield in 1998. Differences among years were mainly due to rainfall, as total rainfall between cotton planting and harvest was 75 cm in 1996, 53 cm in 1997, and 37 cm in 1998.

In 1996, only the main effects of N rate and aldicarb were significant for yield. The 78 kg N ha^{-1} rate had yields that were 503 kg ha^{-1} greater than the 0 kg N ha^{-1} rate (Table 4). Yield did not differ between the 78 and 112 kg N ha^{-1} rates. Application of aldicarb increased yield by 79 kg ha^{-1} over the control in that year. In 1997 and 1998, the main effects of N rate and aldicarb

Table 5. Effect of N fertilizer rate on cotton fiber properties.

		Fiber property				
Year	N rate	Fiber length	Uniformity ratio	Fiber strength	Micronaire	Hunter's +b
	kg ha^{-1}	mm	%	kN m kg^{-1}	units	%
1996	0	27.8	81.3	287	3.69	6.4
	78	28.6	82.0	294	3.84	6.6
	112	28.6	81.9	290	3.88	6.8
	LSD$_{(0.05)}$	0.2	0.5	6	0.09	0.1
1997	0	27.5	81.6	277	3.68	7.0
	78	28.6	82.6	294	3.93	6.9
	112	28.8	82.6	297	3.91	7.0
	LSD$_{(0.05)}$	0.3	0.6	7	0.16	ns†
1998	0	27.8	81.9	290‡	4.42‡	7.3
	78	27.8	81.9	313	4.72	7.8
	112	27.8	82.2	309	4.43	7.9
	LSD$_{(0.05)}$	ns	ns	7	0.18	0.2

† ns indicates N rate main effect was not significant from analysis of variance.
‡ The winter cover × N rate interaction was significant for fiber strength and micronaire in 1998.

and the N rate × aldicarb interaction were significant. The nature of this interaction was similar in both years as aldicarb increased yield at all three N rates, but the yield increase was greater at 78 and 112 kg N ha^{-1} rates than at the 0 kg N ha^{-1} rate. Neither the cover crop main effect nor any interactions with cover crop were significant for yield in 1996 or 1997. In 1998, the winter cover × N interaction was significant. In that year, there was a trend for yield to increase as total N in the fertilizer and the N in the cover crop increased to about 90 kg N ha^{-1} and then decreased with additional N (Fig. 3).

Averaged over N rates, yield response to aldicarb was greatest in 1997 as yield loss due to thrips damage averaged 9% in 1996, 48% in 1997, and 35% in 1998. Although thrips numbers were not that different among years (Table 2), damage to cotton seedlings not protected with aldicarb was also greatest in 1997 (Table 2). All et al. (1995) reported that yield losses due to thrips on cotton not protected with aldicarb were greatest in dry years. Our results agree with their findings. In our study, rainfall totals at 2 wk after planting were 0.1 cm in 1996, 0.8 cm in 1997, and 2.8 in 1998. By 3 wk after planting, substantial rainfall occurred in 1996, and total rainfall at that time in that year was 10.9 cm while the total was 1.68 cm in 1997 and 2.8 cm in 1998. At 4 wk after planting, rainfall totals were 12.95 cm in 1996, 2.53 cm in 1997, and 5.8 cm in 1998. Similarly, although we did not find substantial numbers of immature thrips in our study, Faircloth et al. (2002) reported an apparent inverse relationship between juvenile thrips populations and rainfall. This suggests that perhaps including rainfall totals with thrips evaluations may enhance future research on postemergence treatment decisions for thrips.

Winter cover did not have a substantial impact on fiber properties in 1996 or 1997, as was found earlier (Bauer and Busscher, 1996). In 1998, the fiber strength and micronaire response to N depended on winter cover (Fig. 3). As occurred for yield in that year, both fiber strength and micronaire increased as total N in the cover crop and the fertilizer increased to about 90 kg N ha^{-1}. Additional N only marginally affected fiber strength,

Table 6. Effect of aldicarb on cotton fiber properties.

Year	Aldicarb	Fiber length	Uniformity ratio	Fiber strength	Micronaire	Hunter's +b
		mm	%	kN m kg^{-1}	units	%
1996	Control	28.2	81.7	289	3.87**	6.5**
	Aldicarb	28.4	81.8	293	3.74	6.7
1997	Control	27.9**	81.9**	286*	3.81	7.2**
	Aldicarb	28.9	82.6	293	3.86	6.8
1998	Control	27.6**	81.6**	296**	4.4**	7.7
	Aldicarb	28.0	82.3	312	4.7	7.6

* Indicates control and aldicarb means within year are significantly different at $P \leq 0.05$.
** Indicates control and aldicarb means within year are significantly different at $P \leq 0.01$.

but total N above 90 kg N ha^{-1} resulted in a substantial decline in micronaire (Fig. 3).

The influence of N on fiber length, length uniformity ratio, strength, micronaire, and Hunter's +b for all 3 yr is shown in Table 5, and the effect of aldicarb on these fiber properties is shown in Table 6. Values for fiber elongation were very high (>9.0%) for all treatment combinations in all years so that variable is not shown. Values for Rd (reflectance, a measure of whiteness) are also not shown because it was only influenced by N rate in 1998 where the 0 kg N ha^{-1} rate was 3% higher than the other two N rates. For both 1996 and 1997, cotton grown without N fertilizer had fiber that was shorter, less uniform in length, and weaker and with lower micronaire than cotton grown with 78 or 112 kg N ha^{-1} (Table 5). Hunter's +b increased with increasing N rate in 1996, but there was no difference among N rates in 1997. In 1998, neither fiber length nor length uniformity were impacted by N rate while Hunter's +b of the cotton grown without N was lower than from the cotton grown with the other two N rates.

Terry (1992) reported that the only fiber property affected by aldicarb treatment was fiber length uniformity. Perhaps partially because we found larger yield differences between aldicarb and the control in our study, aldicarb had a greater influence on fiber properties. Aldicarb application affected fiber length in 1997 and 1998, length uniformity in 1997 and 1998, fiber strength in 1997 and 1998, micronaire in 1996 and 1998, and Hunter's +b in 1996 and 1997 (Table 6). When differences for fiber properties did occur in our study, the cotton that received aldicarb generally had higher values for these fiber properties than the cotton that did not receive aldicarb. Because of the separation in time between thrips damage to cotton and the formation of fiber properties in the cotton bolls, it is likely that differences that did occur were due to the effect of aldicarb on the early-season growth of the crop rather than a direct effect on the fiber properties themselves.

In summary, when plants were stressed by thrips damage, stands in both of the winter cover treatments that included crimson clover were greatly reduced in the later years of the study. Further research into remedies to this problem is needed to increase the value of this legume as a cover crop for cotton. Although planting cover crops to increase residue amount has been primarily a concern for soil erosion, others have shown that they can increase subsequent crop yield through other mechanisms. Gallaher (1977) showed that soil remained wetter and crop yields were higher when rye was left as surface mulch than when aboveground parts of the rye were removed in a conservation tillage system. Daniel et al. (1999) found rye had the highest biomass of several cover crop species tested and more water in the soil where rye was grown. Perhaps the low biomass produced by the cover crops in our study, especially during the dryer years of 1997 and 1998 when soil water preservation would have been more critical, limited the ability of the residues to greatly affect soil water beyond what occurred in the no-cover-crop plots. Aldicarb protected the cotton seedlings from thrips damage and lowered thrips populations. Cover crops did not have much influence on either thrips populations or thrips damage either with or without aldicarb. The value of using aldicarb in improving yield and fiber properties, though, depended on rainfall and N level. These additional factors need to be incorporated in developing IPM-based cropping systems.

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